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WAR MEDICINE AND SURGERY

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TREATMENT OF BURNS.

BURNS differ in severity, some scarcely requiring any treatment at all, others being rapidly fatal; and this variation causes difficulty in assessing methods of treatment. Early reports on a new burn therapy are especially liable to be misleading, because a small number of cases of burns rarely gives a truly representative sample. The perfect cure has been found prematurely on more than one occasion, as is shown by the history of tannic acid and triple dye. This is the background against which modern methods of treatment have to be examined.

Comparison of different burns is made easier if the severity of the lesion is described in terms of two features that have an important influence on the prognosis—the extent and the depth. The extent can be estimated roughly from the following figures, which show the percentage of the total body surface constituted by the various parts: head, 6%; trunk, 40%; upper limb, 8%; lower limb, 19%; hand, 2%; foot, 3%. The depth of the burn may be assessed in degrees, of which there are three: in the first degree there is erythema of the skin; in the second degree there is partial destruction of the skin, with or without vesication; and in the third degree there is total destruction of the skin. As the clinical courses of first and second degree burns are usually much the same, they have been grouped together by some writers as superficial, while the third degree burns are described as deep. It is not always easy, even for the most experienced, however, to distinguish between second and third degree burns. Small islets of epithelium from sweat glands or hair follicles may be overlooked, and a second degree burn classed as third degree. When this mistake in diagnosis is made, undue credit may be given to the therapy, since the sparing of these islets provides cells from which the whole skin can be regenerated by growth and metaplasia.

There are other difficulties in comparing different series of burns. One is the variation in the rate of healing for different parts of the body. Healing is slow on the dorsum of the finger joints. It is most rapid on the face, less on the upper extremity, less still on the lower extremity, and slowest on the dependent flexor aspects such as the back of the knee. It is more rapid in the young than in the old. Moreover, the fate of the patient is sometimes determined by incidental complications such as the inhalation of hot smoke or the development of pneumonia.

There is good agreement as to the correct general treatment of burns, and this in itself makes it difficult to evaluate the various kinds of local treatment. Some 70% of the deaths following burns are due to shock, and any local measures that are combined with appropriate anti-shock treatment are likely to gain reflected glory. Those who criticize the indiscriminate use of tannic acid, claim that part of its excellent statistical record is due to the fact that it was introduced at a time when the general treatment of burns was being improved.

In view of these difficulties, it is not surprising that burn therapy is in a state of flux. Since burns are such an important war-time injury, however, the subject is of very great interest, and the literature on the following aspects has been discussed: (*a*) minor burns; (*b*) first-aid treatment of major burns; (*c*) burn shock; (*d*) cleaning of the burnt area; (*e*) tanning of burns; (*f*) saline baths and *tulle gras* treatment; (*g*) use of compression bandages and rest; (*h*) skin grafting; (*i*) special burns; and (*j*) complications.

Minor Burns.

A minor burn is a first or second degree burn, not larger than the area of one side of the hand (twenty-eight square inches in the adult), and not involving the hands, face, feet, genitals or perineum. Patients with such burns are relatively common at first-aid posts, and these centres can provide all the treatment required for them. The area is cleaned gently with soap and water, and covered with "Vaseline" gauze, *tulle gras* or any such simple dressing. Unless there are facilities for cleaning the burn very thoroughly, a coagulant dressing should not be applied, in spite of its advantage of permanency. Morphine may be required to relieve pain.

The importance of considering these minor burns separately is that they must not be allowed to vitiate the statistics concerning burns in general or to influence unduly one's ideas of burn therapy. They almost always heal readily, whatever the treatment applied.

First-Aid Treatment of Major Burns.

Advice about the first-aid treatment of burns has often been issued in the form of slogans, rather than of principles, and consequently insufficient account has been taken of variable factors, such as the severity of the burn and the time interval between the first-aid and the hospital treatment. If the burn is a minor one, hospital treatment is unnecessary, and final treatment may be given along the lines already indicated. In the case of major burns, minimum first-aid treatment should be given. Pain should be relieved by an adequate dose of morphine, which is half a grain for an adult with a severe burn. Fluid should be given by mouth and the patient kept warm. When the hospital is within two hours' distance, no local treatment is required, apart from covering the exposed burnt areas with clean cloth or with a 2% sodium bicarbonate compress.

In wartime, however, many major burns occur which cannot receive hospital treatment for some hours or even days. Local treatment is given in such cases with the object of diminishing fluid loss and preventing infection. A useful dressing for this purpose is a water-soluble jelly with 10% tannic acid and 5% sulphadiazine. This should not be applied to the hands, face, feet, genitals or perineum; they are treated with an aqueous emulsion of 5% sulphadiazine or with boric ointment. If the eyes are affected, 2% "Butyn" ophthalmic ointment is applied to them. In some cases it may be possible to give 500 cubic centimetres of plasma to supplement the treatment for shock.

Under whatever circumstances a burn is treated, all precautions should be taken to avoid infecting it. One should not accept the easy view that there are certain burns in which infection is inevitable; for this inevitable infection usually comes from such controllable sources as the upper respiratory tract or the hands of the patient or attendants.

Perhaps the most confusing advice about the first-aid treatment of burns is that which concerns the use of coagulants. These could probably be dispensed with altogether in ordinary civil first-aid practice, but they are sometimes life-saving when a patient with extensive burns is many hours distant from hospital treatment. The advantage of the use of coagulants as a routine measure for minor burns has to be weighed against the danger of tanning infected or otherwise unsuitable areas. Moreover, if the first-aid worker uses a tanning method, he has assumed the responsibility of beginning a form of treatment which cannot be easily varied subsequently.

Burn Shock.

The keen controversy about various forms of local treatment, and the appearance of the apparently serious local injury must not be allowed to obscure the importance of burn shock. Local therapy cannot be safely undertaken until shock has been controlled.

The shock produced by burns is characterized by the constancy with which hæmoconcentration occurs. On account of this, plasma or serum is the ideal transfusion fluid. The degree of hæmoconcentration has been used too as a guide to the amount of plasma required. Black's formula is:

$$\text{Plasma required (in litres)} = 5 - \frac{500}{\text{Hb}}$$

where Hb = percentage of hæmoglobin (Haldane) after the burn has occurred. For example, if the hæmoglobin percentage is 111, then 500 cubic centimetres of plasma are required; if the hæmoglobin is 125%, a litre of plasma is necessary.

The formula devised by Harkins is based on the hæmatocrit reading. It is as follows: 100 cubic centimetres of plasma are required for every point by which the hæmatocrit reading exceeds 45, provided that the plasma proteins are above 6 grammes per 100 cubic centimetres. If the plasma proteins are x grammes less than 6 grammes per 100 cubic centimetres, an addition of $25x\%$ has to be made to the calculated figure for the plasma required.

These formulæ give some assistance in the calculation of a dose which is difficult to assess on clinical grounds, and they are now widely used. The magic of the clear-cut figure, however, must not be allowed to obscure the unreliability of the basic data. The blood volume prior to the burning can only be surmised; the blood volume subsequent to the burning changes from hour to hour, and a calculated figure, if true at all, is true only for the time at which the calculation is made. The difference between these two figures is what the clinician wants to know, and its margin of error is the sum of the errors of the two individual figures.

In practice, the variation given by different methods of calculation is sometimes considerable. In one case the plasma requirement was 1,000 cubic centimetres according to one formula, and 1,850 according to another. The fact that this variation was described as "not therapeutically significant" seems to indicate that little would have been lost if the calculations had been dispensed with altogether. Nevertheless, hæmatocrit readings or, what is essentially equivalent, hæmoglobin estimations or red blood cell counts, form an important qualitative guide to the condition of the patient, and this importance is greatly increased if serial readings are taken. During the first day hæmoconcentration should be measured at four-hourly intervals, and for the subsequent week an estimation should be made once a day. The red blood cell count is probably least frequently used as a measure of hæmoconcentration; but, if facilities are available, some workers employ all three types of measurement. In addition, plasma protein estimations are made, since it has been found empirically that the concentration of these proteins often diminishes after burns. It is not clear why this diminution should occur; one would expect the exudate passing through the capillaries to have a rather lower protein content than plasma, and the concentration of plasma protein to rise somewhat; but, in any case, the finding of a low percentage of plasma protein is taken as an indication for further plasma transfusion.

One important feature of plasma transfusion for burns is that the best results are obtained by giving relatively small amounts (300 to 500 cubic centimetres) every four to six hours, unless a large transfusion is made essential by a serious reduction in blood volume. By this method the dose is spaced out over a period of a day or more. The decrease in plasma volume cannot be corrected by an initial massive transfusion, for two reasons. While plasma is being administered some is being lost through the permeable capillaries, and the greater the amount administered, the greater the rate of loss. Again, plasma loss continues after a severe burn for some forty hours or more, though perhaps one-half of the total loss may occur in the first hour.

The shock following a burn often develops slowly, since a loss of some 30% of the plasma volume usually occurs before marked clinical symptoms appear.[4] This places added importance on laboratory investigations. Apart from the special features which hæmoconcentration introduces into burn shock, the treatment of the condition is the same as for shock in general.

Cleaning of the Burnt Area.

After measures have been taken to prevent or treat burn shock, the burnt area is cleaned in preparation for local treatment. The aim is to convert the burn into a surgically clean wound. It is therefore essential that all attending personnel should be adequately masked, and that full precautions should be taken against sepsis.

The question of whether a general anæsthetic is required is decided by the condition of the patient and the preference of the surgeon. The argument against full anæsthesia is that it may cause or accentuate liver damage.

If the burned patient is still clothed, adherent and burned clothing is soaked off in water at 100° F. Dirt is then removed, first from around the burnt area, by swabbing with moist pledgets of cotton wool. Water at body temperature and white soap are used; green soap, gauze and scrubbing brushes are avoided, since gentleness is as important as thoroughness and quickness. The soap is finally irrigated off with normal saline solution.

A 1·5% solution of C.T.A.B. (cetyl trimethyl ammonium bromide) has been used in an alternative method of cleaning fresh burns. The area is swabbed first for two to three minutes with this solution and then with saline solution. C.T.A.B. is an effective cleaning agent, and apparently harmless to the tissues.

Difficulties are introduced when the burn is covered with heavy grease or fuel oil. There are three stages in the removal of such contaminants. First the major portion is taken off by means of a solvent. The best one is pure, salt-free, animal lard, but alternatives are glyceryl monooleate, highly purified mineral oil and hydrogenated vegetable fats, such as "Crisco". The solvent is applied on cotton wool swabs. Next, the remaining grease, as well as the excess solvent, is removed with a detergent solution. A mild alkali-free bar soap, known as "Ivory" soap, dissolved in sterile water, is a suitable detergent, but proprietary detergents are also available. The third stage is to swab the burn with sterile normal saline solution. Ether and spirit are unsuitable for the removal of grease, since they damage the tissues.

After thorough cleaning of the area, blisters are opened and redundant skin is removed. Some surgeons then change gloves before undertaking a more detailed surgical toilet and washing the burn a second time.

Tanning of Burns.

At the beginning of the present war tannic acid was generally accepted as a satisfactory local treatment for burns. An extensive trial under war conditions, however, has shown that it is unsatisfactory in the following circumstances.[5]

1. It is unsuitable as a routine treatment of third degree burns. These burns require skin grafting if they are extensive, and tannic acid coagulation is not a suitable preparatory treatment for skin grafting. A tan usually separates as a result of epithelial growth beneath it, or as

a result of infection. The former cannot occur in large third degree burns, and the latter is undesirable. Sometimes the tan is removed with a knife, but this causes further trauma; sometimes it can be removed by continuous irrigation with Dakin's solution, applied at about the sixth day, when the edges are beginning to lift; this is more satisfactory, but is not always readily carried out. Further, surviving epithelial remnants, which are usually found in otherwise deep burns, are frequently destroyed by tannic acid.

2. When applied circumferentially to the hands or feet, tannic acid hinders venous and lymphatic circulation, and so tends to cause necrosis or chronic dactylitis, as well as fixation and loss of function. If it is used on the face, contractures and ectropion may ensue, and the cornea then becomes exposed to injury. It is particularly dangerous on the eyelids, since they become fixed for days or even weeks. If applied to moving parts, the tan is liable to crack and permit the entrance of infection; it is consequently unsuitable in flexures and in the ano-genital region.

3. Old or infected burns should not be tanned, since this converts the area involved into a third degree lesion.

Various methods of applying tannic acid have been introduced, and various antiseptics have been added to it, but none of these modifications constitutes an important advance. New coagulants have also been employed, of which the most important are silver nitrate, triple dye and 3% sulphadiazine in 8% aqueous solution of ethanolamine.

Silver nitrate has one fundamental difference from tannic acid:[5] it forms a tan outside the tissues, rather than a precipitate with the tissues. This happens because soluble chlorides in the body fluids react with it and so protect the protein. If silver nitrate is used in conjunction with tannic acid, the tannic acid merely functions as a reducing agent of the nitrate and hastens the outside tanning, rather than the surface coagulant action. In this case a tan is formed very quickly.

The trend towards the use of silver nitrate combined with tannic acid, rather than tannic acid alone, can be correlated with a new outlook on burns. Tannic acid fixes tissues in the sense that it prevents them from yielding toxic products for absorption; but such absorption is now thought not to be of much consequence. On the other hand, the escape of plasma is considered to be extremely important, and this escape is combated well by the use of a firm external eschar, such as that given by the combination of tannic acid and silver nitrate. Tanning methods therefore have their greatest field of usefulness in those extensive burns in which the loss of plasma threatens life.

Gentian violet or triple dye (1% gentian violet, 0·1% brilliant green and 0·1% euflavine in water) gives a more supple tan than tannic acid, and so covers flexures well. The dyes are bactericidal. They form a coagulum more quickly than tannic acid, but they are rather expensive, and at present difficult to obtain.

The sulphadiazine solution is not the only form in which sulphonamides are used in the treatment of burns, since these drugs may be given locally or orally as part of any of the standard treatments. Sulphadiazine in solution is, however, the most satisfactory sulphonamide for burns.[6] It is applied with a spray, once every hour on the first day, once every second hour on the second day, and less frequently on the third and fourth days. Wet dressings of the same solution should be applied to the edges when they begin to curl up on the tenth to twelfth day. It forms a transparent, pliable eschar. Because of the transparency, any pus that develops beneath is visible, and because of the pliancy it may be used for the face, eyes, hands, feet, joints and ano-genital region. It does not coagulate living tissue, and does not stain the linen. Because the eschar is formed so slowly, the method is sometimes painful. The drug is absorbed at first, and the level in the blood is usually two to eight milligrammes per 100 cubic centimetres. The film later becomes impermeable, and by the sixth day the drug disappears from the blood. Cases of poisoning have, however, been reported. It is possibly a dangerous method for old or alcoholic subjects.

Saline Baths and Tulle Gras Treatment.

The saline bath treatment is an excellent method for old septic burns, and, in general, as a preparation for skin grafting. It is also suitable for burns of the extremities, especially as it makes active movement possible during treatment. It is contraindicated for fresh burns when shock is present.

The limb affected or, if necessary, the whole patient is immersed in a 2% saline bath which is kept accurately at 100° F. The bathing is carried out for about four hours each day, and is usually painless after the first two occasions.

Between baths the area is dressed with *tulle gras* covered by gauze kept constantly moist with saline solution. *Tulle gras* is prepared from curtain net of two millimetre mesh. The net is freed of sizing (by being boiled), cut into four inch squares, and placed in a biscuit tin, with greased paper to separate the layers. A mixture of ninety-eight parts of soft paraffin and two of balsam of Peru is then added, and the whole is autoclaved. The net becomes impregnated with the paraffin. *Tulle gras* has the two virtues of allowing the escape of discharge through the mesh, while preventing the granulations from being torn when the dressings are changed. It is painlessly floated off at the beginning of the bath.

Saline bath treatment makes extra work for the attendants and is possible only in a hospital where sufficient personnel can be spared to prepare the saline solutions, clean the baths and superintend the treatment. It also carries a danger of cross-infection, which can be eliminated only by the use of sulphonamide on the wounds and by scrupulous attention to the disinfection of the bath.

The advantages of the saline bath treatment may be summarized as follows: early return of function; protection of surviving epithelium; control of infection; freedom from pain; and preparation for skin grafting in the shortest possible time.

A modification of this treatment is the use of Bunyan-Stannard envelopes. These enclose the affected part in a transparent coated silk covering. They can be most easily adapted to the limbs, in which case the proximal end is sealed to the skin in a water-tight junction by two overlapping turns of special, webbed, adhesive strapping. There is an inlet through which the warm irrigating fluid is admitted. After some twenty minutes the fluid is drained off through the outlet and the envelope then acts as a dressing. There is sometimes difficulty in keeping the ends water-tight, especially when the part affected is not a limb. The bags have a life of two to three weeks.

Saline solution may be used for the irrigation, but sodium hypochlorite in saline solution is more popular. The solution is prepared by the electrolysis of sodium chloride, a method which does not give an alkaline product. There are 1% of sodium hypochlorite and a large excess of sodium chloride in the solution "Milton" that is usually employed. This is strongly hypertonic and has to be diluted to a 5% concentration before it is isotonic. The resulting dilute solution is usually referred to by the rather confusing term "5% 'Milton'" or "5% electrolytic sodium hypochlorite". It is claimed that hypochlorite cleans the burnt area by its slight solvent action on pus and mucus, and that it is stimulating to the living tissue. The method has the general advantages of the saline bath treatment. It is most suitable for septic burns of the limbs. It is also one solution to the difficult problem presented by a combined burn and fracture.

Use of Compression Bandages and Rest.

In treatment by the use of compression bandages and rest[1][6] the burn is cleaned in the usual way and then covered with a sterile compression bandage. The principle is that exudation of plasma is prevented by the compression. The burn is covered first with fine mesh "Vaseline" gauze strips. On top of these are placed flat gauze dressings, followed by fluffed sponges, which are bound on with a gauze roll. Firm uniform compression on the wound and the surrounding tissues is then obtained by applying sterile cotton waste or sea sponge and then

binding it with gauze. The whole dressing is made secure with adhesive tape. The affected limb may be splinted in the position of function.

The dressing remains untouched for eight to fourteen days, unless daily inspection shows that the compression is not being maintained. When the dressing is taken off, it will usually be found that first or second degree burns have healed, and those of third degree are covered with a brownish, adherent, crusted exudate. This is removed by the use of pressure dressings moistened with saline solution, and the area is then ready for skin grafting.

The method is comfortable after the initial stage, and morphine or codeine may be used to relieve pain in the early period. The advantages of the method are: control of shock; protection from infection; absence of fixation or destruction of viable skin; adequate drainage; and suitable preparation for skin grafting.

Skin Grafting.

Regardless of the local treatment used, completely destroyed skin frequently has to be replaced by a skin graft. To await spontaneous healing when an area of more than about three square inches is involved, is to delay recovery considerably and to prejudice the functional result. Even when skin is able to grow in from the periphery, it is often poor in quality. It is now believed that, in the past, skin grafting was used too little and too late.

The results of skin grafting are good only if the surface is adequately prepared. As soon as the granulations are level with the skin, intensive preparation with locally applied sulphanilamide and saline solution dressings is carried out and a split graft is applied. Pinch grafts are a second choice, but may be necessary if the area is very large.

Immediate skin grafting is also used in the treatment of burns. It sometimes gives the most rapid and best cosmetic result, but is reserved for patients who are in good condition and who have small third degree burns.

New skin formed over a burnt area is poorly supplied with blood. It should be rubbed lightly once a day with hydrous wool fat for six weeks after healing occurs.

Special Burns.

Further experience has recently been gained in the treatment of "airman's burns" and burns resulting from electricity or chemicals.

The "airman's burn" is unlike any burn seen in civil life. It is due to sudden exposure of unprotected parts of the body to intense heat, as from a fire in the cockpit.

The characteristic lesion involves the wrists and hands, especially on the dorsal surfaces, and also the exposed parts of the face and the neck. The best treatment is to prepare for skin grafting as soon as possible. This can be done by the use of saline baths or saline compresses. Digits must be carefully separated so that burnt surfaces are not in apposition. The eyes are not often seriously burnt, because they are protected by the orbicularis reflex, but they should be examined early, before the lids are closed by œdema, and 1% atropine drops should be instilled, whether the cornea is damaged or not. The maintenance of the patient's morale is very important.

Electric burns all involve the full thickness of skin, and the treatment is excision and immediate skin grafting.

Chemical burns in general are treated by immersion of the part in running water. Contact with a small amount of water may be harmful. The subsequent treatment is the same as for thermal burns.

A special type of chemical burn is the phosphorus burn,[2] which is usually caused by the "phosphorus liquid" of incendiary bombs. When the phosphorus ignites, it becomes converted into phosphoric acid, which penetrates deeply. Phosphorus particles themselves may become deeply embedded from the force of the explosion. The aim of the preliminary treatment is to neutralize the phosphoric acid and to inactivate the unchanged phosphorus.

If the skin is contaminated with a liquid containing phosphorus, one must not dab it with a handkerchief or other dry material. The liquid readily soaks into dry material, and ignites when a large surface becomes exposed by capillary action. The first step is to moisten the surface and add an alkali powder such as:

Heavy magnesium oxide	10%
Borax	5%
Sodium bicarbonate	85%

The powder is worked up into a paste and then wiped off. The procedure is repeated as long as effervescence continues. An alternative way of neutralizing the acid is to wash the burn with sodium bicarbonate solution, but this is likely to displace unignited phosphorus to other parts of the body.

The next step is to convert the free phosphorus to inactive copper phosphide. This cannot be done efficiently by the usual method of adding a 1% solution of copper sulphate, since at least 1,600 parts of solution would be required for one part of phosphorus. The best preparation to use is a copper sulphate paste such as:

Copper sulphate	22·5%
Glycerin	67·5%
Starch	5%
Water	5%

This is applied as a thin layer and rubbed in. It emulsifies the phosphorus and then reacts with it rapidly. The glycerin prevents the material from drying. The paste is wiped off when phosphorus can no longer be smelt in the wound.

A final application of alkaline powder is made to deal with remaining acid. This powder is worked up as before and bandaged on. The burn may subsequently be treated by irrigation with a slightly alkaline solution such as sodium hypochlorite. It is probably the persistence of small amounts of acid in the tissues that is responsible for the pain and slow healing usually associated with a phosphorus burn.

Complications.

Even under ideal conditions a patient with a severe burn may require five months' stay in hospital,[3] but second degree burns are usually healed in three weeks. There are certain complications, however, which spoil these results.

Infection is the commonest complication. Even in recent times it has not been uncommon for two-thirds of the patients treated for burns in hospital to develop pyogenic infection. These results can now be greatly improved since we have become aware of the main sources of this infection, and since the sulphonamide drugs have been available for treatment.

Toxæmia is now considered rare, except as a result of infection. Necrosis of the liver which can result from this toxæmia and was once described as "the one constant feature of the pathology of burns", may also be caused by infection, tannic acid, anæsthetics and sulphonamides.

Pneumonia is especially liable to occur in burns of the face when hot air is inhaled. If the patient becomes hoarse and complains of pain in the mouth, throat or neck, the subsequent onset of pneumonia is to be feared.

A secondary anæmia constantly affects severely burned patients and may prevent skin grafts from taking. Mental disturbances sometimes result from fear of pain and disfigurement. Contractures and resulting deformities are due to inefficient treatment as well as to deep, extensive burns. The severe septic burn is still a major problem.

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